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GRADES OF PEAT AND MUCK FOR SOIL IMPROVEMENT

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INTRODUCTION

The need of organic matter for soil improvement creates a problem that becomes increasingly acute. By far the most valuable constituent of a soil is its organic matter, and depletion of soil humus has become an important factor in impoverishing cultivated soils and subjecting them to erosion. The destruction and loss of soil organic matter by tilling, leaching, and other active agencies is taking place much more rapidly than it was accumulated. A deficiency in soil humus, already deplorable in long-established farming regions, cannot continue without imperiling the most vital resource of the Nation.

On account of its content of weed seeds and the high price and scarcity in most localities, stable manure cannot often be used profitably as the sole source of organic matter. To prevent further avoidable deterioration in the structure and desirable properties of soils, the use of crop residues and legumes is quite general. The principal disadvantage, however, lies in the relatively rapid decay of the organic matter of green crops, leaving the soil without any marked improvement after the lapse of a few years. There is, therefore, a general demand for a source of organic matter that would provide a satisfactory and relatively persistent material, and would maintain improvements in mineral soils when used in greenhouses, nurseries, golf courses, parks, and gardens that are seriously impoverished in their present condition.

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The consumption of peat imported from Europe is rising steadily and has reached a value of nearly $1,000,000 annually (*5*),[1] while the value of domestic production in 17 States, influenced by this development, is reported to be greater than the import. Such sums as these emphasize the economic and practical importance of peat.

As a source of organic matter the better grades of peat play a significant part in modifying the physical, chemical, and biological properties of mineral soils and in making them more favorable for the growth of plants. Different kinds of peat are available in considerable quantities in the United States but are not uniform in composition and properties. The relative value of various peat materials in the preparation of desirable composts has been studied by many investigators. The value of peat in mixed fertilizers as a conditioner, or in composts with other plant residues and a variety of animal waste products, has been recognized in older agricultural countries for many years. In the composting process peat and muck undergo bacterial decomposition with alternate layers of barnyard manure, or chemical changes by the addition of commercial fertilizers used in an amount equivalent in fertilizing value to well-decayed manure. Work of this character is done in several States and some of the methods have been reported in United States Department of Agriculture Circular 252 dealing with the preparation of peat composts (*2*).

More recently, however, the direct application of peat and muck to practically all soils containing an inadequate supply of organic matter has gained in practice. Its principal disadvantages are, however, that certain types of peat, though they may appear desirable when utilized for soil improvement, will inevitably cause difficulties. For this reason knowledge of the several kinds of peat and a proper understanding of the nature of peat deposits from which commercial products are to be obtained is basic to a satisfactory solution of various problems of soil improvement. Although in part a problem of local economic significance, the selection of suitable areas of peat and their utilization for different purposes is also important in a State- and Nation-wide program.

The value of widely differing classes of peat and muck and their several effects on soil improvement have not yet been satisfactorily determined. Many more experiments and analyses are needed before definite relationships can be developed. Nevertheless, observations made in the past few years on this subject deserve attention. The recent studies by Hitchcock (*7*), Langley (*8*), Laurie (*9*), McCool (*10*), Snyder and Wyant (*12*), Sprague (*13*), Vandecaveye (*14*), Waksman (*15*), and others give useful information regarding various peats and the method to be followed. Some of the conclusions reached are tentative, but they afford ample justification to increase the scope of such studies. In the following pages the characteristics of several classes of peat are described with special reference to those which appear practicable for the purpose of soil improvement. The composition and properties of the principal types of peat material should not be lost sight of in the attempt to determine their relative value for increasing the organic matter content of mineral soils. Their respective value should be compared from the standpoint of

[1] Italic numbers in parentheses refer to Literature Cited, p. 30.

(1) changes effected in defective structural characteristics, lack of moisture-holding capacity, or other unfavorable physical properties of the soil; (2) as a source of organic matter and soluble nutrients, and (3) response in the character and amount of growth made by cultivated plants.

PEAT DEPOSITS, THEIR NATURE AND CHARACTERISTICS

To most people peat and muck mean merely a sample of organic matter, generally from the surface of a deposit. A more adequate conception can be obtained only from information on an entire vertical section or profile of a peat area down to the underlying mineral soil. It is important to bear in mind that peat deposits, under natural conditions, consist as a rule of different layers of peat superimposed upon one another. These layers differ markedly in composition, and show considerable range in physical properties, organic constituents, and reaction to the activity of micro-organisms and growing plants. When drained or very dry they shrink and may smoulder or burn more or less completely if set on fire.

Areas of peat represent different stages in a process of development which in many instances has proceeded since the close of the ice age and is still in progress. They vary in size and depth, in the number and thickness of layers, and in such characteristics as color, reaction, height of water level, and the features with which each layer is preserved, making identification possible. Various kinds of peat have been described in Department Bulletin 802 (*1*). They have been illustrated in Department Bulletin 1419 (*3*), which discusses also some of the more important structural differences between definite profiles of peat deposits in this country.

DISTRIBUTION OF PEAT DEPOSITS IN THE UNITED STATES

Accumulations of peat and muck are found widely distributed. They occur under a variety of conditions and in many States. A map, based largely on reports of the Federal Soil Survey, topographic sheets of the United States Geologic Survey, and on statistics on wet lands in need of drainage, was published in the Yearbook of the Department of Agriculture for 1921. A map showing the general distribution of peat deposits and the approximate locations of operating plants that manufactured commercial peat products in 1918 accompanies Bulletin 253, issued in 1926 by the Bureau of Mines of the Department of Commerce (*11*).

In a more recent publication (*4*), the peat deposits of the United States have been broadly divided into three major groups, differing in important characteristics and regional relationships to surface vegetation, climatic conditions, and time relations. The geographic limits established for each group must necessarily be arbitrary, and each group unit includes areas of peat of a transitional character. A generalized map of these regions is reproduced in figure 1. The major groups of peat land are distinguished from each other as follows:

The first main group comprises areas that contain a surface layer of moss peat varying greatly in thickness and in amount of woody material. It includes flat and raised bogs, heaths, and coniferous swamp forests, as well as peat areas of an intermediate character.

The deposits are generally acid in reaction, more or less poorly decomposed, and deficient in plant nutrients. The group is confined chiefly to the cool and humid northern portion of the New England and the Great Lakes States and along the Pacific coast from northern Washington into Alaska. The peat materials are more or less leached, lack available nitrogen and mineral salts, notably lime, but have a moderately high content of decomposable organic matter. They are of relatively recent origin and do not appear to have undergone decomposition to so great a degree or to so great a depth as in the more southern States.

The second major group includes areas of peat from New Jersey westward to Ohio and toward South Dakota. It comprises continental deposits that have a more or less complex structural development. The various layers consist of fibrous peat derived from reed

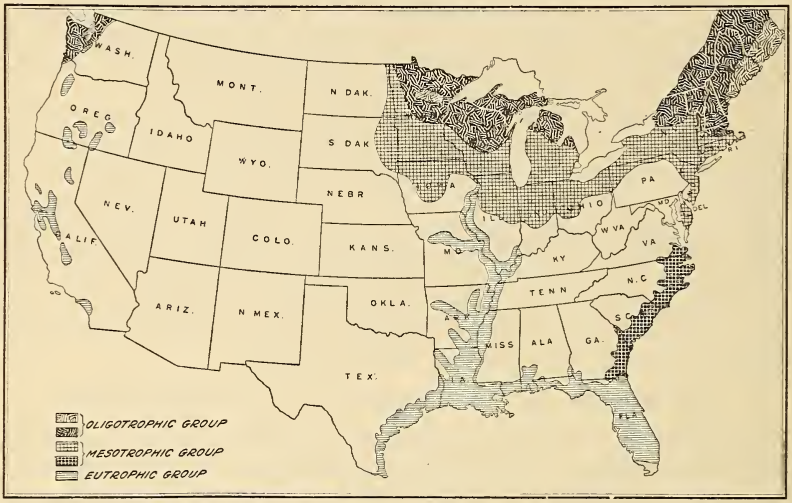

FIGURE 1.—Map of the United States showing regions in which the major groups of peat land occur.

and sedge marshes and of woody materials from swamp forests of mixed conifers and hardwoods. Some of the layers of peat are darker in color and partly decomposed. Lime, phosphorus, and nitrogen may be present in varying quantities owing to the greater depth at which decomposition has taken place favored by a modifying influence from the underlying mineral soils of the region, by evaporation and warm summers. A belt of peat deposits, represented by the Dismal Swamps along the Atlantic Coastal Plain from Virginia to Georgia, has been included in this main group. These peat areas are predominantly woody and acid in reaction. Their relationships and possible uses are not well known, but their basic economic utility is that of timber production.

The third major group consists of deposits of peat containing fibrous material derived from saw grass, cane, tule, and other marsh vegetation subject to periodic flooding. They are generally neutral to alkaline in reaction and show varying degrees of decomposition. Outstanding members of this group are the subtropical Everglades

of Florida, the areas of peat in the valley of Mississippi River, the semiarid peat lands of California, and the deposits in the valleys of the Klamath and Willamette Rivers in Oregon.

CHIEF CLASSES OF PEAT AND THEIR ORIGIN

Since the main purpose of this circular is to present comparisons of the relative value of the more important kinds of peat utilized for soil improvement, it is desirable to concentrate attention on the characteristics of four outstanding types. The relationships between the several kinds of peat and the units of natural vegetation

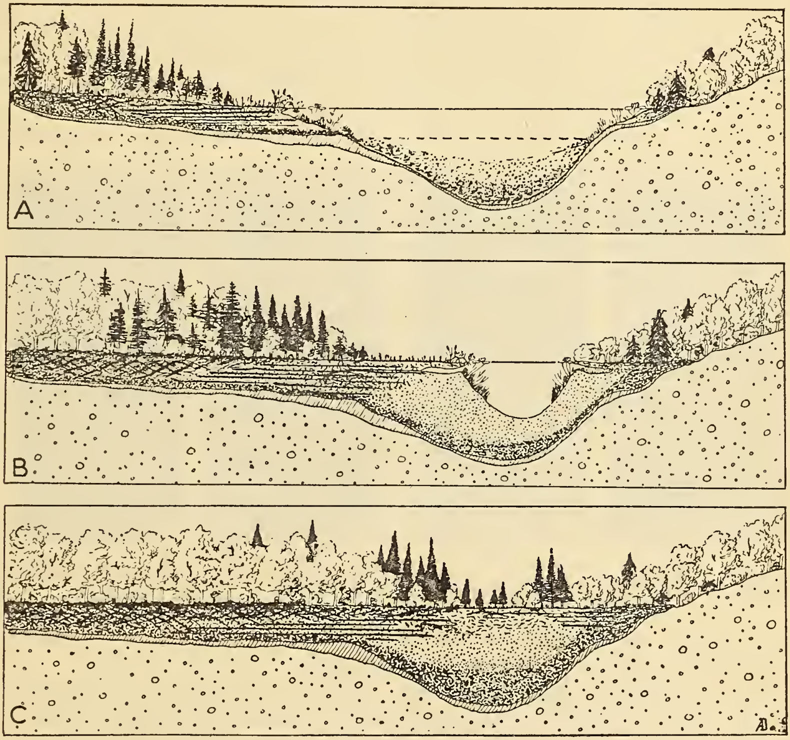

FIGURE 2.—Graphic presentation of stages of vegetation in the formation of a peat deposit over a depression that contained an older body of standing water. It illustrates the formation of *A*, sedimentary; *B*, fibrous; and *C*, woody peat.

that have given rise to them in a succession of stages will become evident from the diagram illustrated in figure 2 and the descriptions below. Information of this kind will be of assistance to those who are interested in a standard of comparison and in acquiring a general understanding of the economic and practical possibilities of peat and muck.

CHARACTERISTICS OF SEDIMENTARY PEAT

In any shallow lake or pond, such as may be seen rather generally in Northern and Central States, the history of a peat deposit begins with a stage of vegetation associated with the open water (fig. 2).

It consists of microscopic organisms, submerged plants, pond weeds, waterlilies, and similar forms of plant life. The yearly addition of decaying bodies of such organisms, deposited in depressions and basins, accumulates in the form of a soft, oozy, structureless peat. It contains plant remains that are recognizable and material which has lost all traces of its origin and has become changed into an amorphous residue. With these variations are associated gases such as methane, hydrogen, carbon dioxide, and others produced by the activity of certain (anaerobic) micro-organisms that decompose the organic matter.

Sedimentary peat, of which several varieties are shown in figure 3, is fine-textured, plastic, and often gelatinous when wet, but hard and horny when dry. In some localities it occurs compacted into a dense, impervious organic sediment; in other places it contains bits of tissue from roots and leaves, a variety of seeds, wind-blown pollen, quantities of shells from mollusks, diatoms which have siliceous skeletons, or sand, silt, and clay. Some varieties of this organic

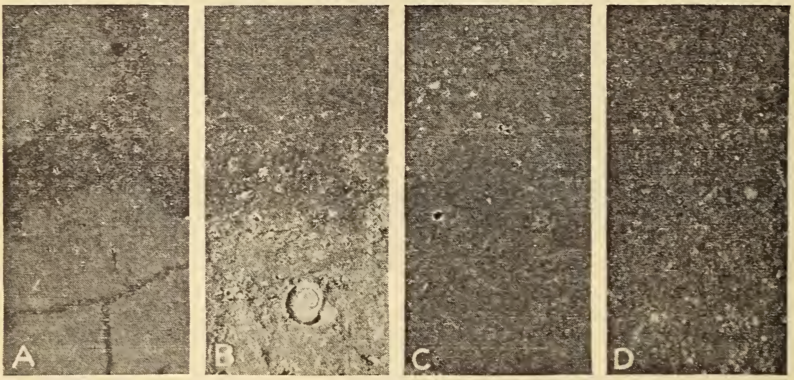

FIGURE 3.—Varieties of sedimentary peat: *A*, Colloidal sediments from submerged aquatic vegetation, plankton, and organic matter in suspension: *B*, over marl from shells and stonewort (*Chara* sp.); *C*, containing diatoms; *D*, jellylike material from algae.

material are nearly alkaline in reaction and comparatively high in lime but others range from acid to neutral.

The significant feature of the organic content of sedimentary peat is that in a plastic colloidal state it performs the function of a binding material with a soil. It is the seat of important chemical reactions and absorbs and exchanges dissolved substances from solution. When air-dried it shrinks greatly and becomes relatively inert. Owing to this tendency to unfavorable compaction and hardening, sedimentary peat with a high content of organic matter of the size of colloidal particles does not offer a satisfactory material for decreasing the cohesion or plasticity of certain soils when mixed with them. The evidence available at present indicates that, in general, the characteristics of sedimentary peat do not have the value for imparting changes in granulation, aeration, and other desirable properties to be discussed later.

DIFFERENT GRADES OF REED AND SEDGE PEAT

The second stage in the development of a peat deposit is generally associated with the encroachment of marsh vegetation upon the lake

or pond in which the free water surface is disappearing by the filling process of the aquatic plants (fig. 2). In this case the dominant vegetation consists either of sedges such as wire grass, saw grass, tule, rushes with cattail and others, or of reeds, canes, and reedlike grasses. The plants make little demand for nutrients. They can grow in water containing considerable proportions of mineral salts in solution, tolerate partial submergence, and root themselves into the soft, miry ooze. They possess a habit of excessive root growth, which in time builds up a firm, coarse to felty fibrous and porous peat layer, made of an interwoven network of underground stems and roots. The plant remains restrict the movement of water and this in turn raises the water level, excludes air to a large extent, prevents oxidation, reduces microbial activity, and thus preserves the accumulation of roots, rhizomes, and residue.

Poorly decomposed plant remains generally form a considerable proportion of the fibrous layer; but in certain cases it may contain dark-colored, structureless residue, derived from more easily decomposing leafy tissue by a complex series of microbiological and chemical changes. Fibrous types of peat, illustrated in figure 4, are often designated as fen peat, low-moor peat, and high-lime peat. They are here separated and classified either as sedge or reed peat, depending on the nature of the flattened rootstocks that predominate in the organic material, and can be recognized by the eye or under the microscope.

Characteristics which meet the requirements of a good grade of reed or sedge peat are based on degree of decomposition, color, reaction, low ash content, and absence of objectionable matter such as coarse woody fragments and injurious mineral salts of iron and sulphur.

A poorly decomposed grade of reed or sedge peat is reddish to yellowish brown in color, acid or neutral to slightly alkaline in reaction, and distinguished by its more or less porous, coarse to finely fibrous structure. When air-dried the mass is brittle and the finer root material tends to break into powdery particles that absorb air and become almost impervious to water. Under moderately moist or drained conditions reed and sedge peat favor the activity of an appreciable number of micro-organisms, especially fungi. They decompose more or less rapidly when their moisture content is favorable and the recognized nutrient deficiencies are remedied by the addition of potash and phosphate fertilizers. Applications of nitrogen and lime are not always required, but should vary according to climatic conditions and soils.

When reed or sedge peat are in a moderately advanced state of decomposition or have undergone cultivation, the material is partly fibrous, and the residual organic matter is dark brown to black in color, fine-grained in texture, and slightly acid to neutral in reaction. This grade crumbles easily and is generally referred to as reed or sedge "muck." It shows marked transformations in comparison with the original parent material. The changes are characterized by an increase in the content of ash and organic complexes that are more or less resistant to further decomposition. There is present also a higher content of nitrogen, mainly as a result of the activity of micro-organisms, but phosphorus and potassium are found

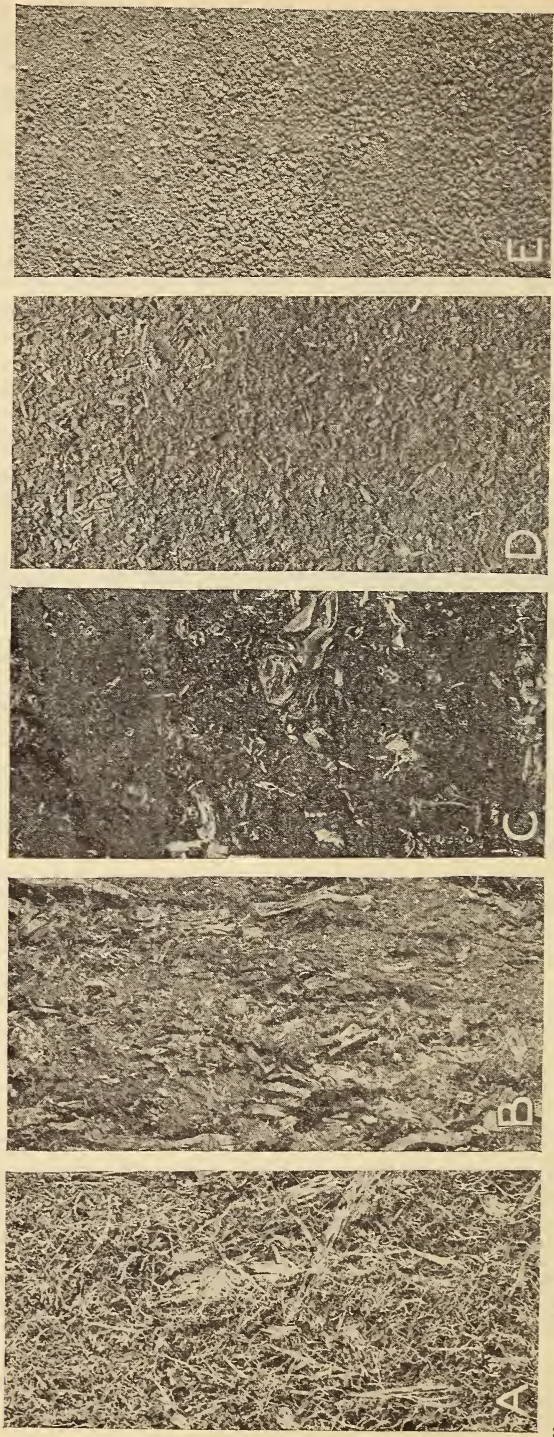

FIGURE 4.—Sedge and reed peat: *A*, Sedge (*Carex*) peat; *B*, tule (*Scirpus*) peat; *C*, reed (*Phragmites*) peat; *D*, shredded reed peat; *E*, reed muck (cultivated).

in small amounts and should be reinforced by the use of commercial fertilizers.

Fairly definite inferences may be derived from the information presented above. Grades of reed or sedge peat that are fibrous and poorly decomposed, when prepared by shredding and sieving, and well mixed with a mineral soil, may be expected to improve the moisture relations, to be more effective as a source of organic matter for microbiological processes, and to develop an organic complex that possesses the characteristics of soil humus. They may thus render possible the development of a crumbly structure in sticky or hard-packed, clayey soils and to that extent exert desirable physical influences. On the other hand, partially decomposed and cultivated grades of reed or sedge peat should be valuable primarily for supplying a relatively inert, organic residue; they may be used more effectively for improving the physical condition of any mineral soil in need of structural changes.

Domestic reed and sedge peat are among the most effective types of organic matter for soil improvement and general horticultural purposes when properly treated. Distinct differences in the growth and density of grasses may be noted between plots receiving applications of reed or sedge peat and the plots left untreated. Grass roots do not penetrate very deeply into the soil, but to promote their development it is important to mix the peat material with the soil thoroughly and evenly to a depth of several inches below the surface. The results have been favorable where less than one fourth of the total volume of the soil is finely shredded reed and sedge peat or the darker-colored, partially decomposed residue designated as muck. In general, plots with light applications show greater gains in soil improvement and relatively better plant growth than plots receiving no additions of peat or muck.

When well mixed with finely pulverized sandy loam and supplemented with moderate amounts of inorganic fertilizer, a grade of finely shredded peat or granular reed and sedge muck, slightly acid to neutral in reaction, is preferred in the preparation of seed beds, topsoil for potting, and top dressing for lawns. The top-dressing mixture, when made in a proportion of 1 part of peat to 5 or 7 parts of loamy soil, may be applied several times during the year with or without fertilizers. For acid-loving plants a grade of poorly decomposed shredded material is required, giving a strongly acid reaction.

A light application of granular muck or of finely shredded peat will work into a heaving clay soil when used as a surface mulch during the winter or in early spring. A mulch may also be used during the season of growth on lawns and putting greens, but to prevent layering or the ridging, illustrated in figure 5, and to reduce losses from washing, the organic matter should be raked thoroughly into the soil. Where it is not practicable to disk, spade, or plow a soil it should be spiked in all directions to facilitate thorough mixing and promote decomposition of the organic material.

A grade of medium to coarse shredded reed and sedge peat is used, frequently, to meet the needs of gardeners, for general use as a surface mulch. Practically all conifers and ericaceous shrubs require a strongly acid grade of material. For deciduous trees, shrubs, and herbaceous perennials and for the protection of foliage plants and

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ferns from injury by frosts or losses of soil moisture, a grade of material should be used that is slightly acid to neutral in reaction. The same material, when thoroughly mixed into the upper few inches of the soil, or to the level of the feeding roots of shrubby and herbaceous plants, makes a soil conditioner of considerable merit. Combinations of shredded fibrous peat with a clay soil are shown in figure 6.

WOODY PEAT

The final stage of native vegetation that establishes itself upon a layer of reed or sedge peat under natural conditions is a swamp forest of conifers, together with deciduous trees (fig. 2). The gradual accumulation of peat above the water level of the original lake,

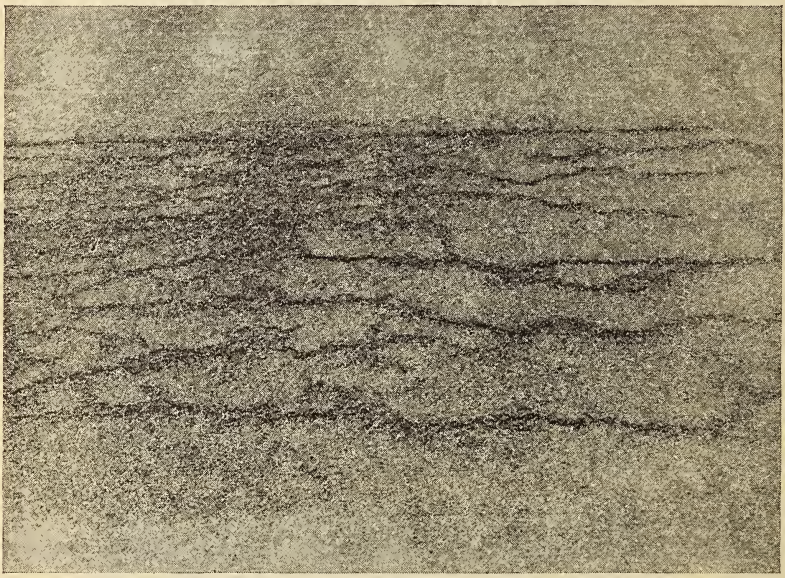

FIGURE 5.—Shredded, coarsely fibrous peat washed out of top dressing on turf by heavy rains and piled in ridges.

moderate aeration, and a vigorously active population of microorganisms, as well as differences in evaporation and shading through tree growth, modify the character of the surface of the marsh and eventually result in new peat-soil features.

The invasion of shrubs and trees into a marsh reaches its greatest development with the subsequent segregation of the swamp forest vegetation into dominant deciduous trees and subdominant trees of conifers, a diversified undergrowth of shrubs, and a ground cover of perennial herbs, ferns, some mosses, wood-destroying fungi, and the like.

Under forest conditions the principal source of organic matter is an accumulation from fallen logs, branches, and roots varying in size and degree of decomposition. Additional marked effects of the influence of a swamp forest are indicated by the litter from leaves and needles, by a considerable contribution of bits of twigs, bark,

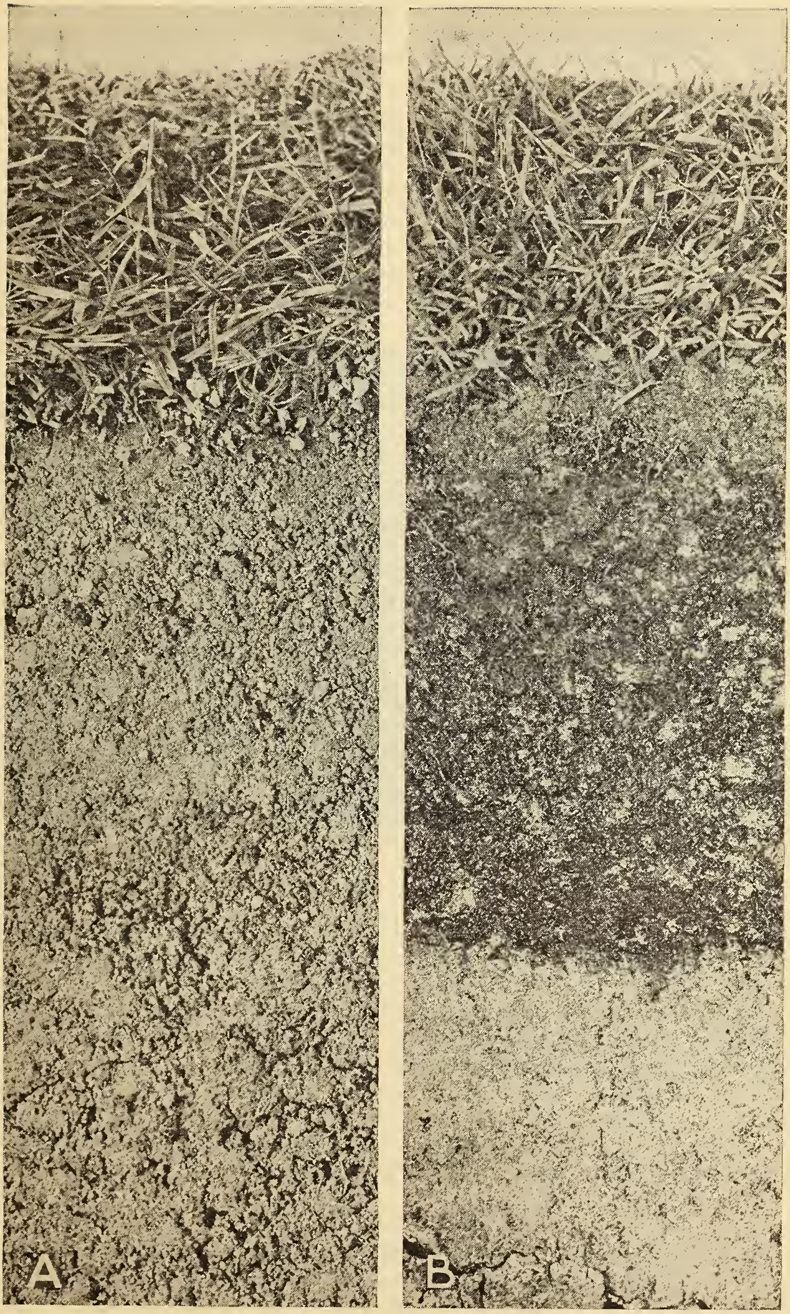

FIGURE 6.—Vertical cross sections of a heavy clay soil (lower portion of *B*) of which one half of the volume is sand in *A*, and shredded sedge peat in *B*.

cones, and fruiting bodies, and by an appreciable amount of crumbly, granular residue (duff or leaf mold) matted together by a meshwork of roots and the mycelium of fungi. This type of organic mixture is shown in figure 7 and classified as woody peat.

Coniferous woody peat derived from spruce, tamarack, cedar, evergreen shrubs, and others has a marked acid reaction, and transformation of the organic matter is very slow. Decomposition changes are mainly the work of fungi and the peat material remains as a more or less sharply defined, coarse, woody layer, brown or dark brown in color, correspondingly poor in mineral nutrients and basic constituents. In the presence of a sufficient supply of lime and other mineral bases to maintain a neutral to slightly alkaline reaction, changes result mainly through the agency of bacteria, earthworms, and similar organisms. The dark-colored, granular woody residue may extend to considerable depth and the peat deposit is then in its final phase in which the principal trees are maple, ash, elm, and to a less extent conifers such as tamarack and cedar.

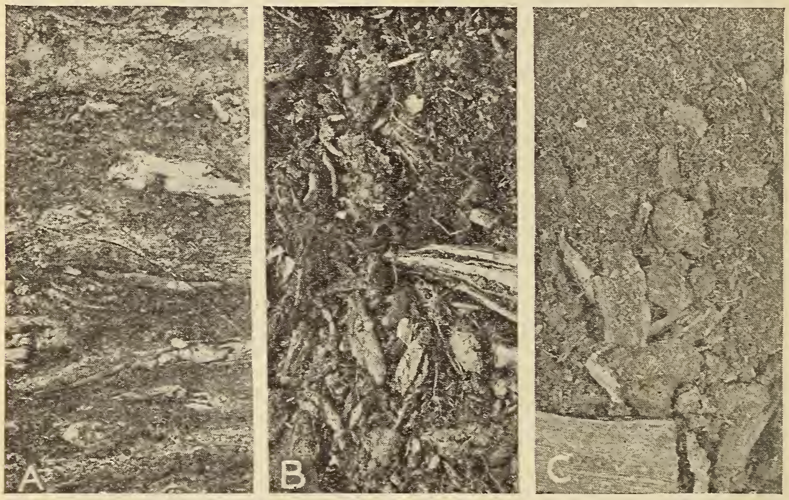

FIGURE 7.—*A*. Laminated woody peat from a variety of shrubs: *B*, poorly decomposed woody peat derived from coniferous swamp forest; *C*, partly decomposed woody material from a mixed conifer and hardwood swamp forest.

Because of the presence of tree stumps and many coarse woody fragments, and the practical difficulty involved in separating the variable quantity of granular residue, woody peat does not constitute a suitable source of organic matter for soil improvement. The chief value of swamp forests and their woody peat seems to be in the tree growth which they are capable of producing.

VARIETIES OF MOSS PEAT

Many of the deposits from Maine to Minnesota illustrate a more northern type of peat which differs markedly in character and composition from the kinds of peat previously described. It is formed predominantly by the small stems and leaves of sphagnum mosses.

Layers of moss peat of varying thickness occur most commonly in the cool and moist northern region of the United States. Some of

the peat areas are flat heath bogs, while others, especially those of northeastern coastal Maine, have a surface which rises from the margin of the deposit to the center, and on that account are known as "high moors." The native surface vegetation is made up largely of various species of *Sphagnum* and a scattered growth of sedges and small ericaceous shrubs, principally leatherleaf, Labrador tea, laurel, blueberries, together with scrubby, dwarfed black spruce and tamarack. There is not much timber growth, owing to the very low amount of soluble mineral and organic constituents in the water retained by the mosses. As shown in Circular 167 (*5*), a layer of moss peat generally overlies a layer of woody peat, but it may occur superimposed upon sedge and reed peat.

The reaction of moss peat is strongly acid. The material is, as a rule, poorly decomposed, spongy-fibrous, light yellowish brown in color, and consists mainly of the remains of sphagnum mosses (fig. 8). It has a uniformly low content of mineral matter and nitrogen and supports a very limited population of fungi and other microorganisms. This is due in part to the high capacity of the tissue of stems and leaves of mosses to conduct and retain water in the meshwork of elongated, absorbing capillary cells.

The chemical composition of these cells does not offer a favorable organic material to microbial activity. It cannot be utilized by them in the absence of oxygen and in a cold, acid, water-logged environment. These conditions account also for the heavy expense involved in reducing the moisture content of moss peat by artificial means. Similar considerations apply to the decomposition of the material when intermixed with a mineral soil. The rate of change is very slow unless the acid reaction is corrected by the use of lime and its nutrient deficiencies are remedied by an application of nitrogen in an available form or by the use of a complete commercial fertilizer.

Coarse-textured fibrous moss peat is supplied to the trade in several grades based mainly on the degree of fineness of shredding the material. It is customary to make a separation of the mechanically shredded moss peat by sieving. Moss peat for stable bedding and poultry litter is relatively coarse and lumpy, while particles of smaller size serve horticultural uses. The finely shredded fraction affords a more satisfactory material for soil improvement because it exhibits certain well-defined properties of organic matter that are most important from a soil standpoint.

Moss peat which has undergone a moderate degree of decomposition is brown in color, partly fibrous, contains an appreciable quantity of dark-colored residue, small woody fragments, and coarse fibers from cotton grass; it is considerably more resistant to further decomposition than the less altered, younger material.

The improvement obtained from additions of moss peat to mineral soils will be described below. Its uses for plant growth are varied and have been noted elsewhere (*5*). For a well-branched, slender root development of cuttings of many plants and transplanted seedlings, a mixture of equal proportions of coarse sand and light-colored poorly decomposed shredded moss peat is preferred in both propagating benches and frames. The mixture should be renewed every few years or whenever the moss peat shows signs of undergoing decomposition. Likewise for conifers and broad-leaved evergreen shrubs such as rhododendrons, kalmias, azaleas, and others, a

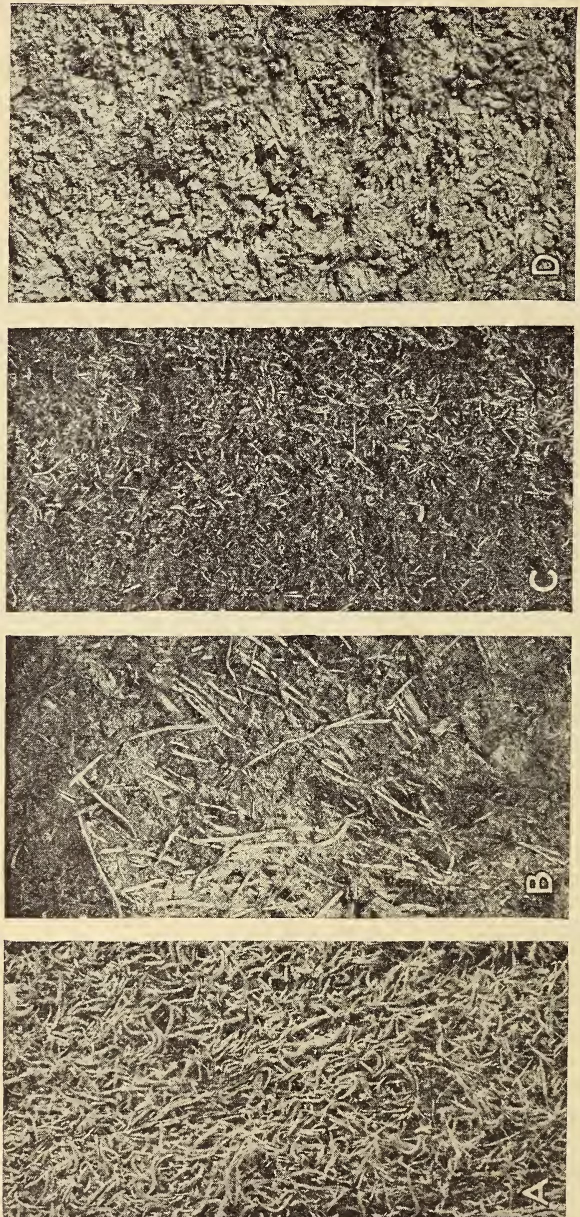

FIGURE 8.—Varieties of sphagnum-moss peat: *A*, Coarsely fibrous; *B*, partly decomposed; *C*, slightly decomposed; *D*, fibrous.

shredded moss peat is more effective when worked down to the root level in the soil and fresh material is applied to the surface as a mulch at intervals of a few years. The proportions should be varied for particular plants, soil conditions, and climate.

Evergreen trees and shrubs and many herbaceous perennials are benefited by surface mulching with an acid, coarsely shredded moss peat, especially where much depends upon the conservation of soil moisture, in checking weed growth, fungi, and soil organisms, or providing protection to plants from frost injury.

PHYSICAL PROPERTIES OF SPECIFIC KINDS OF PEAT AND MIXTURES WITH SOILS

Peat materials exhibit certain peculiarities in their physical properties which exert also considerable influence upon conditions of mineral soils and plant growth. Some of the effects are direct, others are indirect.

DIFFERENCES IN VOLUME-WEIGHT

One of the most striking characteristics of peat and muck is their weight as compared to mineral soils. Department Bulletin 802 (*1*) gives interesting data for comparing the volume-weight of the chief classes of peat in various degrees of decomposition. Additional information on this point for entire profiles will be found in Technical Bulletin 214, a more recent publication of the United States Department of Agriculture (*6*). The figures given in table 1 are based on data taken from these bulletins. Knowledge of the actual weight of a peat material as well as of a soil, affords a basis upon which to calculate the amount of organic matter, water, pore space, and nutrient constituents present; it affords also a ready means of comparing treated and untreated soils as to the properties associated with structural changes.

TABLE 1.—*Physical properties of different kinds of peat*[1]

Type of peat material	Weight per cubic foot	Maximum water-absorbing capacity		Moisture equivalent	Degree of acidity
		Moist	Air-dried		
Moss peat:	*Pounds*	*Percent*	*Percent*		*pH*
Poorly decomposed	9	3,235	2,000	628	[2] 3.8
Partly decomposed	9	2,420	1,485	558	[2] 3.8
Reed peat:					
Poorly decomposed	17	888	666		
Partly decomposed	26	871	653		
Sedge peat:					
Poorly decomposed	25	911	561	339	[3] 5.5
Partly decomposed	36	905	309	314	[4] 5.9
Woody sedge peat		300	299	108	[3] 4.6
Woody peat	48	1,070	278	447	
	56	643	162	346	[2] 3.7
Sedimentary peat	34	348	157	211	[2] 3.5
	56	693	262	320	[4] 6.8
	75	414	195	239	[4] 6.2

[1] Data from Department Bulletin 802 (*1*) and Technical Bulletin 214 (*6*), of the U.S. Department of Agriculture.
[2] Very acid.
[3] Acid.
[4] Slightly acid.

It may be remembered conveniently that a cubic foot of water weighs 62½ pounds and that a similar volume of clay soil weighs from 65 to 75 pounds, while sand weighs from 85 to 95 pounds per cubic foot.

In the case of different peat products obtained in the open market the approximate volume-weights are as follows: Poorly decomposed moss peat ranges from 10 to 15 pounds a cubic foot; for reed peat the range is from 20 to 35 pounds, and in the case of cultivated and kiln-dried varieties from 35 to 45 pounds a cubic foot; sedge peat generally weighs from 18 to 36 pounds for every cubic foot, according to its state of disintegration and moisture content.

For practical purposes and calculations it is often desirable to know approximately the space covered by a unit volume of the various kinds of peat. From the figures given above, it is to be expected that, bulk for bulk, a ton of poorly decomposed moss peat, or reed and sedge peat, requires more storage space and will spread over approximately two to four times the area that will be covered by a ton of the same kind of peat decomposed to an advanced degree such as muck.

The following figures in tables 2 and 3 are based on work of the Bureau of Chemistry and Soils in cooperation with the United States Golf Association Green Section at Arlington Experiment Farm, Rosslyn, Va. The data are instructive in showing some of the physical changes that take place in a heavy compact clay soil to which reed peat in different degrees of decomposition, and acid shredded moss and sedge peat have been added.[2]

TABLE 2.—*Effects of different kinds of peat on the physical properties of a clay soil* [1]

Type of peat added to clay soil in equal proportions by volume	Weight per cubic foot	Loss on ignition	Moisture content	Maximum water-holding capacity
	Pounds	*Percent*	*Percent*	*Percent*
Moss peat, poorly decomposed	38.63	14.1	2.22	104.6
Sedge peat:				
Poorly decomposed	48.75	16.1	2.09	76.0
Partly decomposed	45.62	24.4	2.81	88.1
Reed peat, partly decomposed	55.74	17.2	2.52	72.4
Reed muck:				
Largely decomposed	58.54	20.4	3.38	67.9
Well decomposed	60.92	24.4	4.07	76.0
Untreated clay soil	79.26	3.7	.76	42.1

[1] Analytical data by I. C. Feustel.

[2] All of these observations were made on plots cropped to grass; hence the quantitative determinations include additions of organic matter from the growth of grass roots.

TABLE 3.—*Effects of moss and sedge peat and certain fertilizers on the properties of a clay soil* [1]

Treatment of plot	Weight	Loss on ignition	Moisture content	Maximum water-holding capacity	Total nitrogen (N)	pH
	Lbs. per cu. ft.	*Percent*	*Percent*	*Percent*	*Percent*	
Check clay soil	74.90	3.7	0.76	41.2	0.05	[2] 4.6
Check-urea	74.27	3.8	.83	41.2	.06	[2] 4.6
Moss-urea	46.19	12.0	1.44	92.8	.12	[2] 4.4
Sedge-urea	56.17	15.7	1.78	72.6	.23	[2] 4.2
Check-lime-urea	76.77	3.3	.76	40.3	.04	[3] 6.4
Moss-lime-urea	51.18	10.7	1.45	84.6	.12	[3] 5.8
Sedge-lime-urea	59.29	14.4	1.72	72.2	.22	[2] 5.3
Check-sulphate	76.15	3.4	.76	38.7	.04	[2] 4.1
Moss-sulphate	44.31	12.1	1.55	93.0	.13	[2] 4.1
Sedge-sulphate	56.17	15.1	1.66	68.4	.23	[2] 4.2
Check-nitrate	74.90	3.4	.82	37.3	.05	[3] 6.0
Moss-nitrate	46.19	12.1	1.64	93.8	.14	[2] 5.1
Sedge-nitrate	54.92	15.5	1.85	74.9	.26	[2] 4.7

[1] Analytical data by I. C. Feustel. [2] Acid. [3] Slightly acid.

A consideration of these figures shows the relative effect of the different kinds of peat in modifying structural conditions and lowering the volume-weight of a soil. Obviously the more the organic matter that is present in a sandy or clayey soil, the less is the weight of a cubic foot of the soil. When applied at similar rates by volume and worked into a soil to even depths, a mixture made with brown, poorly decomposed grades of peat is lighter not only in the sense of being lighter in weight for equal volumes, but also looser and in much better granulation and tilth when compared either with a soil mixture containing a grade of black well-decomposed peat residue or with the untreated sandy and clayey soil.

RELATIONSHIPS TO PORE SPACE

Peat and muck are more porous than mineral soil of any kind. This pore space varies with the texture and structure of the several types of peat and may be partially or wholly replaced by either air or water. Generally speaking, pore space is related to volume weight and equal to the amount of moisture which a given quantity of organic matter can retain when saturated with water. But it should be noted that the results represent approximations; for example, the high figures actually obtained for absorption of water by moss peat are related in part to the peculiar cell structure of the material.

The effect of adding peat to mineral soils is always to alter the structural characteristics and to increase the air space especially of cohesive and plastic soils. A high pore space in clay and silt soils is favorable to the growth of plant roots, to aeration, and the movement of moisture, gases, and dissolved salts. Mixtures of peat and mineral soil tend to produce a loosely aggregated condition and to make corresponding changes in granulation. This improvement of the soil crumb structure is important and clearly

apparent by the force required to penetrate a compact clay which has a high degree of stickiness as compared with the same clay soil that received varying applications of peat. If the original cohesion of a unit volume of clay soil is taken as 100 percent, the relative force necessary to penetrate a mixture of clay containing an equal volume of peat is reduced by more than one half.

There is much variability in the porosity of different mixtures of peat with soil at different moisture contents and consequently in the permeability and ready movement of water, air, soluble salts, or micro-organisms in such mixtures. From the standpoint of pore space shredded fibrous materials are more effective in sandy soils and are more suitable for increasing the pore space of cohesive and plastic clays and silty soils defective in drainage.

On the other hand, the changes in structural conditions produced by kiln-dried peat or highly decomposed peat residue are not as valuable as those resulting from applications of grades of fibrous peat that have been shredded to a fine texture. Residues of decomposed or carbonized peat materials tend to greatly increase granulation and percolation in soils, but the moisture content is deficient and gravity is the principal force that causes the movement and removal of any excess water. Rain percolates downward and out of the reach of plant roots, hence percolation may take place so readily that the amount of water available for growth may become rather small. The physical value of highly decomposed organic residues or of artificially dried and charred peat is therefore quite distinct from the value of less-decomposed grades of peat that actually hold moisture and reduce percolation and the loss of water within certain limits.

It is possible, on the basis of various observations, to obtain an estimate of the change brought about in pore space by the addition of different classes of peat and muck.

A treatment with poorly decomposed, shredded fibrous types of peat is most effective in increasing the percentage of pore space when compared with the weight of a unit volume of soil in which the interstitial spaces have been decreased mechanically by trampling or chemically by the action of deflocculents and certain fertilizers. It is followed in degree of effectiveness by mixtures of moss and reed peat and varieties of peat materials in a state of partial decomposition. In both cases the pore space of such mixtures of soil and peat involves an increase in moisture-holding capacity.

The porosity of a mineral soil is increased also by the addition of artificially dried and carbonized peat, but water movement, aeration, and evaporation may take place so readily as to be detrimental to growing plants, especially in sandy soils.

WATER-RETAINING CAPACITIES

Peat and muck possess varying powers of retaining moisture in different forms and for different uses. When added to a mineral soil, probably no other source of organic matter plays a greater part than peat in maintaining a supply of moisture in the soil

against the pull of gravity and of fixing, in whole or in part, various substances in solution contained in the ground water or in applied soluble fertilizers.

The wide range exhibited by different kinds of peat in the ability to absorb water and ammonia has been shown by data presented in Department Bulletin 802 (*1*). A measure of the vertical variations in moisture-holding capacity of entire peat profiles is illustrated by data given in Technical Bulletin 214 (*6*).

The values shown in table 1 indicate that moss peat possesses the greatest capacity for absorbing water available to plants; the moisture retained in the meshwork of capillary cells of the leaves and stems composing moss peat ranges from 1,500 to over 3,000 percent of the weight of the peat and represents water held largely in an absorbed form. Sedge and reed peat hold as much as 500 to 1,000 percent of moisture and the maximum water capacity approximates more closely to the pore space. By comparing tables 2, 3, and 5, the effects of moss, reed, and sedge peat may be seen in a clay soil possessing a relatively low power of retaining moisture, due primarily to its texture and compactness.

It is important to note that changes in the moisture-holding capacity of a peat material occur as a result of decomposition. Well-decayed and cultivated varieties of peat, designated as muck, have a smaller capacity of absorbing and retaining water.

Desiccation of peat materials through excessive drainage and in periods of drought, as well as artificial drying by means of high temperatures, also, reduce the capacity of the organic matter to retain moisture. Consequently, organic residues such as charred peat when added to mineral soils tend to allow moisture to pass through with less retention. They increase moisture losses by percolation and do not maintain an adequate supply of available water in the soil mixture in comparison to less decomposed grades of peat.

In some fibrous peat materials the water relationship is dominated by the presence of colloidal organic material which in common with other gelatinous varieties of peat has the property of retaining large proportions of moisture termed "water of imbibition." Grades of reed and sedge peat with a high content of colloidal sedimentary material exhibit this water relationship, and associated with it, a certain degree of plasticity and cohesion. Upon drying they are markedly affected by shrinkage and compaction. The intractable, hard clods formed under such conditions are, of course, very inadequate means to improve mineral soils. However, varieties of these types of peat, containing an appreciable proportion of sand, silt, marl, or diatoms, are not in such cases colloidal in character.

The capacity of a peat material for holding water when subjected to a magnified gravity pull—that is, to a constant centrifugal force 1,000 to 3,000 times the force of gravity—is termed its moisture equivalent. It is the percentage of water that is not free to move but is held bound within the internal surfaces of the component parts of the peat material. While not considered a critical moisture content it, nevertheless, represents a lower limit of available water that may not satisfy the needs of plant growth. Data in Technical Bulletin 214 (*6*) show moss peat to have a moisture equivalent which

amounts to 82 percent of the water content in the original material. Against this may be set the value obtained for sedge peat which ranges between 38 and 51 percent. In mixtures of peat and mineral soil the moisture equivalent bears probably a more or less general relationship to the various combinations and textural grades.

The moisture equivalent is a constant that may be used in the determination of other constants such as the hygroscopic coefficient. It is that part of the water content which a dry organic material absorbs when exposed to air saturated with water vapor. From methods previously used by other workers it appears that the hygroscopic coefficient is approximately 0.37 time that of the moisture equivalent. It represents the amount of water in thin films and coatings held so firmly by organic matter as to be unavailable to plants and for microbiological activity. Moreover, the rate of any chemical change is inappreciable compared with the rate in peat and muck that contain more moisture than their hygroscopic capacity.

Moss peat has a high hygroscopic power and can condense and withdraw water from moist air to a greater degree than reed or sedge peat. In this way moss peat may be a contributary cause of the persistent wetness of the material under natural conditions, thus reinforcing the losses caused by evaporation. However, further work is desirable to establish a correlation which undoubtedly exists between peat materials of different kinds, their various moisture constants, and capacity to yield available water.

CHEMICAL COMPOSITION OF PEAT AND MUCK

The chemical complexity of peat and muck and the nature of the residue which develops in the soil as humus have long been difficult problems of investigation. It was inevitable, therefore, that much of the earlier analytical work and the existence of certain organic acids and compounds was open to doubt.

In the last decade very full critical accounts and new analyses have appeared. They cannot be examined appropriately at this time. The following refers only to such information as appears necessary for the purposes of this discussion.

RELATIVE ABUNDANCE OF MINERAL FOOD CONSTITUENTS

Numerous analyses of peat materials, collected in important areas under a variety of environments, have shown that mineral nutritive ingredients, such as phosphorus and potassium, are present in very small amounts. The content of lime is variable and the content of available nitrogen is relatively low, more or less resistant, and a limiting factor for particular plants; the nitrogenous organic matter is generally found to be in the form of unavailable compounds.

The data in table 4 are selected from analyses given in Department Bulletin 802 (*1*) and Technical Bulletin 214 (*6*), while the figures shown in table 5 refer to peat materials that are practically identical with those used in the field tests noted in tables 2 and 3.

TABLE 4.—*Fertilizer constituents of various kinds of peat* [1]

[On basis of 100 parts moisture-free peat]

Nature of peat	Total nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Calcium (Ca)	pH
	Percent	*Percent*	*Percent*	*Percent*	
Moss peat:					
Poorly decomposed	0.79	0.05	0.06	0.12	----------
Do	.75	.10	.03	.47	[2] 3.8
Partly decomposed	.87	.02	.02	.23	[2] 3.6
Largely decomposed	1.35	.05	.05	1.78	----------
Reed peat:					
Poorly decomposed	2.29	.16	.05	3.02	----------
Largely decomposed	3.07	.17	.03	4.99	----------
Sedge peat:					
Poorly decomposed	1.63	.07	.04	.50	----------
Partly decomposed	2.10	.05	.04	1.52	----------
Do	2.34	.06	.09	3.87	[5] 7.1
Woody sedge peat	3.14	.42	.09	1.29	[3] 4.6
Woody peat:					
Coniferous	.82	.14	.16	.35	[2] 3.7
Do	.86	----------	----------	----------	----------
Deciduous	1.73	----------	----------	----------	----------
Sedimentary peat, colloidal	.74	.03	.02	.42	[2] 3.5
	2.12	.19	.31	2.59	[4] 6.2
	2.71	.23	.005	8.41	[4] 6.8

[1] Data from Bulletin 802 (*1*) and Technical Bulletin 214 (*6*).
[2] Very acid.
[3] Acid.
[4] Slightly acid.
[5] Neutral.

TABLE 5.—*Chemical analyses of several kinds of peat and muck used in tests* [1]

[Percentage basis of dry material]

Type of peat and muck	Ash content	Organic matter	Acidity (pH)	Total nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Calcium (CaO)	Maximum water-holding capacity
	Percent	*Percent*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sedge peat:								
Poorly decomposed	6.03	93.97	5.5	3.33	0.04	0.03	1.49	506
Partly decomposed	5.33	94.67	4.0	1.76	.11	.07	.64	433
Reed peat, partly decomposed	8.24	91.76	4.1	3.06	.15	.07	2.57	395
Reed muck:								
Largely decomposed	18.31	81.69	5.6	3.84	.34	.22	6.12	262
Well decomposed	24.04	75.96	4.9	3.45	.29	.35	4.91	209
Kiln-dried	22.92	77.08	4.6	3.26	.22	.30	4.96	89

[1] Analytical data by I. C. Feustel.

The data in tables 4 and 5 indicate definitely that peat and muck are deficient in necessary mineral food constituents and have little value as fertilizer material. The first step in raising the fertility of peat land is usually an improvement of those water and nutritive conditions which operate as limiting factors on plant growth. Nutrient deficiencies of peat and muck used for soil improvement must, accordingly, be remedied by the application of mineral commercial fertilizers, or corrected by the addition of such chemical constituents as growing plants require.

NATURE OF ORGANIC CONSTITUENTS IN VARIOUS KINDS OF PEAT

The major constituents of peat and muck are organic complexes of carbon and nitrogen. They afford a more definite means of isolating and comparing the composition of organic compounds that

may serve in part as a source of food and energy for micro-organisms and growing plants, and the substances that are resistant to decay. It is only within recent years that attention has been directed to a study of the nature of the organic compounds in peat and muck, and to account for the different processes involved in decomposition and the character of the residual products formed.

Peat and muck are generally devoid of soluble starches, sugars, and fats; the principal constituents are, therefore, more or less inert cellular and fibrous tissues low in nitrogen and ash, and variable in amounts of resins, waxes, and related complex substances. Table 6 shows the differences in the chemical composition of various kinds of peat. The analytical results are taken from Technical Bulletin 214 (*6*) and afford a comparison with other kinds of plant material. They bring out the changes that are taking place in organic matter undergoing transformation by various processes.

TABLE 6.—*Chemical composition of various types of peat* [1]

[On basis of 100 parts of organic matter]

Nature of peat	Total nitrogen	Water-soluble constituents	Hemicellulose	Cellulose	Lignin complex	Ether-soluble material	Alcohol-soluble material	pH
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Moss peat:								
Poorly decomposed	0.59	6.99	24.3	16.9	18.89	1.98	4.25	[2] 3.7
Partly decomposed	.97	5.00	24.6	15.7	18.05	3.27	5.16	[2] 3.8
Do	.89	5.39	19.4	11.3	27.93	3.25	6.31	[2] 3.6
Sedge peat:								
Poorly decomposed	2.49	7.94	6.0	2.7	50.39	1.75	3.85	[3] 5.2
Do	3.72	4.64	8.8	4.1	46.91	.60	1.89	[3] 5.5
Partly decomposed	2.85	2.06	3.8	2.8	59.25	.75	1.98	[4] 7.1
Do	3.64	3.14	9.9	3.0	53.60	.70	2.27	[5] 5.9
Woody sedge peat	3.52	8.89	8.1	2.7	35.64	1.82	7.43	[3] 4.6
Woody peat	1.12	5.10	1.1	.6	33.87	2.29	6.80	[2] 3.7
Sedimentary peat	.79	1.48	.7	1.7	65.90	9.36	7.08	[2] 3.5
	4.05	6.13	3.6	1.1	39.55	.77	2.70	[5] 6.2
	3.52	2.42	4.0	2.7	59.64	.52	2.07	[5] 6.8

[1] Data from Technical Bulletin 214 (*6*).
[2] Very acid.
[3] Acid.
[4] Neutral.
[5] Slightly acid.

CHANGES OCCURRING DURING DECOMPOSITION

To emphasize the differences in the decomposition of organic matter induced by the activity of fungi and bacteria, it is of interest to illustrate the process by the changes taking place in green and stable manures. In the case of these materials practically all the changes are relatively rapid, owing to the presence of numerous fungi and bacteria. They attack first the water-soluble substances, largely sugars, starches, and organic acids, then the celluloses and hemicelluloses, and finally substances such as lignin, fats, and tannins which decompose more slowly. During this process the organic matter darkens in color, nitrogen is liberated in an available form, and only a small amount of the original plant material is left as a residue to increase the amount of " humus " in the soil.

On the other hand, in the case of peat and muck, totally different results are obtained. The very low content of water-soluble constituents, the relatively low amounts of cellulose and hemicelluloses, the

greatly varying content of ligninlike complexes, waxy and resinous material, and the relatively low content of available nitrogenous substances lead to a slow alteration of the plant remains. Decomposition of any cellulose or hemicelluloses present is very gradual and dependent on the amount of available nitrogen. The greater the content of carbohydrates such as cellulose and hemicelluloses the greater is the need for soluble nitrogen required by micro-organisms for their activities and growth. In addition, the high water-absorbing capacity of certain kinds of peat, their high acidity, low soil temperatures, and a lack of bases and other mineral salts are also unfavorable for the development of many micro-organisms active in decomposition. This relationship is chiefly responsible for the slow rate of decay of moss peat and of other coarsely fibrous materials that are strongly acid in reaction, contain cellulose and hemicelluloses, but are poor in soluble nitrogenous substances. It accounts also for their persistence after incorporation into a mineral soil that lacks an available form of nitrogen. Moreover, ligninlike complexes, resinous substances, and waxes are more resistant to decomposition, and hence considerable quantities of solid residue are left, increasing correspondingly the amount of inert products. Hence the value of breaking down coarse peat materials, together with stable manure or mineral fertilizers, in a compost heap.

Sphagnum-moss peat contains considerable proportions of cellulose and hemicelluloses and comparatively little lignin, while the bulk of reed and sedge peat consists largely of ligninlike complexes and other resistant compounds that do not decompose readily under some conditions. It is uncertain to what extent the lignin fraction may serve as food for certain micro-organisms and undergo changes, resulting in a greater increase in nitrogenous substances of microbial origin. It is scarcely justifiable, however, to assume that this complex is incapable of further decomposition. Under well-aerated soil conditions and a favorable moisture content (*15*) the organic complexes in which an enrichment of lignin with nitrogenous substances has taken place may disappear by oxidation processes as well as by the activity of certain soil micro-organisms.

RELATIVE VALUES OF PEAT AND MUCK IN THE MAINTENANCE OF ORGANIC MATTER IN SOILS

The problem of maintaining a proper supply of relatively resistant organic matter is one of great practical importance in soil economy. There is no doubt that peat and muck are relatively more resistant to decomposition than other forms of plant remains and that differences exist in the rate at which the several kinds of peat will decay or resist decomposition when added to a soil. It should be expected also that under favorable conditions of soil moisture, temperature, reaction, and tilth all grades of peat and muck will eventually decay completely. The rapidity of decomposition will depend upon the nature of the plant remains, upon the climate of the region, and upon the proportion of mineral bases in the soil.

Not only the nature and composition of the several kinds of peat will influence the speed of decomposition but also differences in the population of soil micro-organisms that attack various organic complexes. Moreover, different local conditions and soils will modify

still further the trend of the process as well as the amount of persisting residue produced.

From this viewpoint it will be obvious that grades of light-colored fibrous moss, reed, or sedge peat, containing decomposable substances in the form of cellulose, hemicelluloses, and other carbohydrates, should be of higher value as a source of organic matter. On becoming well mixed with a mineral soil the organic material tends to gradually generate carbon dioxide and organic acids through oxidation processes. A further stage consists in the action of these acids and the absorbed water as a solvent agent; this aids in releasing plant food contained in mineral salts, in absorption of bases, and in forming organic complexes as a food supply for micro-organisms and growing plants. Thus the process of decomposition results in the formation of new substances collectively referred to as soil humus. In permeable sandy soils the transformations of organic matter will be considerably greater than in compact clay soils. Sandy soils should receive, on that account, heavy applications of finely shredded, poorly decomposed grades of peat with high absorption capacity, while materials in a more advanced degree of decomposition, showing comparatively little tendency to absorb bases and water, are more effective in improving the conditions of dense clay soils. Mixtures with these grades of peat decompose at a slower rate in the absence of nitrogenous fertilizers, with infrequent or too heavy watering, and in regions of cool climate and acid mineral soils.

Quite different in their effect upon soils are grades of peat that have reached a partial state of decomposition or those of peat areas that have undergone intensive cultivation. Grades of more or less decomposed moss, reed, and sedge peat change mainly through the action of oxidation processes. They show greater resistance to micro-organisms causing decay, chiefly because the content of decomposable substances is already very low. In the absence of fresh organic matter it may be supposed that peat residues or muck will not undergo many reactions when added to mineral soils, and that losses of these residues will vary approximately according to the character of the climate. Sufficient data are not as yet available for a satisfactory judgment to be formed. However, for purposes of improving merely the physical properties of a soil, grades of decomposed peat or muck should be of value to any mineral soil. As organic residual products they exhibit not so much the effects of microbiological decomposition as they reflect a degree of chemical disintegration.

Artificially dried and charred grades of peat and muck show still greater resistance to decay. When thoroughly dry they take up very little moisture, oxidize with extreme slowness, and persist longer than any other kind of organic material when added to mineral soils. Actually, however, carbonized residues of peat and muck do not benefit a soil; they accentuate the effects of drought and do not improve soil conditions to the same extent as grades of peat and muck that decay more readily. Dried and carbonized materials are relatively less suitable because they do not possess water-retaining capacity and do not develop a soil solution and a source of food supply for micro-organisms and roots of plants. Surface

evaporation from such soil mixtures is relatively great; they are subject to leaching by percolating waters and to moisture deficiencies, and changes in the moisture distribution do not replace the losses of water by evaporation.

RELATIONSHIPS BETWEEN COLOR AND DEGREE OF DECOMPOSITION

Color is one of the important aids to the recognition and description of different grades of peat. There is generally a progressive darkening in color as peat material decomposes to muck. This can be well illustrated by comparing the material of a peat deposit exposed in an old open ditch with a freshly cut vertical section, or by examining portions of a peat area that have been under cultivation for different periods of time.

To express the degree of decomposition that has taken place, it has been found practical to employ an arbitrary scale of five divisions. These represent certain more or less definite values to indicate grades of (1) poorly decomposed peat, (2) slightly decomposed peat, and (3) partly decomposed peat, and grades of (4) largely decomposed muck to (5) well decomposed muck.

The natural color of a peat material is a characteristic which assists judgment of quality and value. Light reddish- and yellowish-brown colors almost invariably predominate in poorly and slightly decomposed peat materials. These colors characterize grades that have a relatively low content of mineral matter and tend toward an acid reaction. Mottled yellow and red colors are indications of differences in plant remains and in the rate at which decomposable substances are developing a residue under fluctuations of water content. Mottling is rarely due to the presence of minerals such as iron or its oxidation products.

Partially decomposed grades of peat are usually slightly acid to neutral in reaction, brown, and a shade of gray deserves closer consideration. A grayish tint indicates as a rule the prevalence of mineral matter and to a certain extent the presence of soluble salts. Black tints originate naturally from residual organic matter but in some cases they are produced by anaerobic conditions and hydrogen sulphide.

Very dark brown and black colors serve as the general basis for estimating grades of largely decomposed to well-decayed plant remains. They are the result of active oxidation and of a high proportion of residual material contributed chiefly by the activity of micro-organisms.

Greenish colors may be attributed to the presence of compounds of sulphur and iron, such as marcasite, while a bluish color may be due to vivianite (phosphate of iron). Red colors may also occur in peat and muck containing varying proportions of iron compounds.

Broadly speaking, it may be said that the most marked changes from dark to light colors are found in the peat material nearest the surface of a deposit. The differences in color are much less distinct in areas which have been subjected to drainage and in peat deposits of relatively greater age. The colors stand out sharply and are more strongly contrasted in deposits that are of recent origin or are water-logged and in which the active agents remove oxygen from the organic material.

ACIDITY

Peat and muck that are saturated with water and undergo changes under conditions of insufficient oxygen supply are generally acid in reaction. Any acidity resulting from changes in the height of water table or from ground-water conditions associated with underlying sandy soils is, in part, attributable to the carbon dioxide formed. Where lime and soluble salts are absent, leached out, or displaced, the original content of bases may fall below that representing a neutral reaction; the acidity may then be correlated with a deficiency of calcium or the prevalence of a base-unsaturated condition. In still other cases, acidity may be due to the presence of active organic acids and injurious substances in solution or suspension. Under virgin conditions acid peat materials are found commonly in the cool and humid sections of the United States. Most of the plants in that region can tolerate a fairly wide range of acid reaction and hence it cannot be generally maintained that acid peat materials are injurious to plants.

Peat and muck which have been in contact with appreciable quantities of lime or have fixed certain mineral salts are said to be more or less saturated with bases and to give an alkaline reaction. In deposits of semiarid temperate regions of this country peat materials are not likely to be very acid, because the source of acidity—rainfall and removal of bases by leaching—operates to only a slight extent in drier climates.

A number of methods for determining the degree of acidity and its correction by means of lime have been devised. A convenient measure of acidity is based on the fact that various indicators of a complex nature change in color with respective concentrations of hydrogen ions in solution. Determinations of pH refer, therefore, to values higher or lower than that of distilled water having the neutral pH value of 7. In a corresponding manner the reactions of peat and soil are denoted by numbers higher or lower than neutral when the indicators in them are acted upon by solutions of different acidities or alkalinities.

The prevailing pH reactions of various kinds of peat and muck are listed in the preceding tables. They show that a high acidity is generally accompanied by a low content of lime. However, an acid or alkaline reaction is not necessarily a measure of the amount of lime which the peat material may contain or require. In nearly all cases a chemical analysis may be necessary. The results in the tables listed above show also that the reaction is influenced by the nature of the peat material. The lowest figures are found usually in moss peat while the higher pH values are found in sedge and reed peat.

Acidity, where present, is corrected by aeration and the addition of lime. It is not generally a limiting factor, except through excessive watering and prolonged leaching. It should be added, however, that a limiting factor may be caused by the continued use of certain fertilizer treatments that tend to increase the acidity of a soil. Injury may also be produced by the presence of an excess of soluble salts in ground waters and underlying mineral soils. There is considerable variation in the tolerance of different plants to sol-

uble salts either acid or alkaline in reaction, but most cultivated plants can tolerate only small concentrations of salts in the soil solution. The presence of an excess or of an unbalanced condition of soluble salts in peat materials from salt marshes is therefore a serious drawback to their use in soil improvement. Injury from salt concentrations in heavy mineral soils and from heavy applications of soluble fertilizers can be reduced by the use of poorly decomposed grades of peat low in ash content.

FACTORS RELATING TO AN ECONOMIC PRODUCTION OF COMMERCIAL PEAT PRODUCTS

The difficulties connected with any attempt at manufacturing peat products, the various methods employed and machinery used, cannot be described here. This subject has been discussed elsewhere (*2*, *5*, *11*). It is desirable, however, to emphasize the following points:

The suitability of a peat deposit for commercial use depends upon its origin and its location relative to a shipping point and markets. The acreage of the peat area and the quantity of workable material must be sufficient to warrant production on a large scale for a period of years. The area selected should not be a pond-formed, basin-shaped type of deposit. The depth of the deposit should be not less than 5 feet, and the character of the underlying mineral soil should assure some form of land use after the peat is removed. The outstanding feature in the character of the peat material should be a comparatively low content of colloidal organic material, mineral matter, and of stumps, roots, and coarse woody fragments. It is estimated that each acre 1 foot in thickness can be converted into approximately 150 to 200 tons of air-dry peat.

Facilities of drainage and favorable climatic conditions with relation to length of working season and period of air-drying the peat product are also factors that have a material bearing on the success of the operation.

Some of the methods employed consist in excavating brick-shaped pieces of fibrous peat by means of a specially shaped spade. The pieces are spread and air-dried on the surface of the peat area and later stacked in special drying sheds or in storehouses. In localities where this method cannot be used or larger quantities are required the surface peat layer is plowed to a depth of 6 to 8 inches, or disked, harrowed, and scraped several times during the year.

There is an advantage in carrying on operations late into the autumn and leaving coarsely fibrous peat on the surface of the area to freeze during the winter months. Fibrous peat is broken up by the frost, making the product soft and brittle. It dries better when spread out and exposed to the wind.

Brick-shaped pieces and furrow slices, after being sufficiently dried in the air to a moisture content not greater than 60 percent, are conveyed to the plant in cars or transported on a traveling belt. The material is then passed through a shredding machine. To prevent the formation of combustible dust during shredding and sieving operations it is important not to reduce the moisture content of the raw material to a point where it will pulverize. There are different sizes of shredding machines, and some of them are constructed in a form

more or less similar to the shredders and soil mixers used on a farm. Coarsely fibered peat material and lumpy masses are torn mechanically into particles of different sizes.

It is customary to make an arbitrary separation of the shredded product by means of rotary screens or sieving. Although not generally adopted, one method is used by which a certain proportion of the coarser-grade material is removed from the fine-textured grade, and the two products are afterward baled or bagged separately.

Since labor is an important item of cost, the equipment of a plant and the excavating, spreading, conveying, and shredding of the material should function in close coordination with elimination of needless effort. Based on the performance of experienced producers and well-coordinated plants, the estimated cost of a commercial product of peat and muck is reported to be as low as the peat product manufactured for fuel (*11*).

Artificial drying by pressure and charring of peat by the application of heat are not economical procedures. Such efforts have not been successful and should not be considered in this connection. Moreover, heat-drying changes the properties of the dried peat product and renders it unsuitable for soil improvement and plant growth.

In future the problem of differentiating peat profiles more completely and selecting suitable areas of peat must claim more attention, particularly in view of the potential economic developments.

SUMMARY

In many parts of the United States the very rapid loss of organic matter in soils has serious consequences in deterioration manifested by the loss of a desirable crumb structure, decreased water-holding capacity, and increased liability to erosion and the effects of drought.

The efficiency of commercial fertilizers for soil improvement can be increased materially by maintaining and increasing the content of organic matter of the soil.

A classification of and uniform grading system for domestic peat materials and peat products would avoid difficulties and mistakes of past commercial attempts; it would achieve a better standard of material, greatly influence the further utilization of peat products, and insure a more satisfactory industrial development of selected areas of peat.

The characteristic physical properties and chemical composition of the main classes of peat are described, and the possibilities of several different kinds of peat for improving specific conditions of a mineral soil are outlined.

The improvements obtained from these types of peat are due to several different effects on soils and plants. Some of the influences are physical, chemical, and biological. With adequate additions of commercial fertilizers to remedy nutrient deficiencies of particular crops, the improvement resulting in any one of these conditions is of sufficient importance to justify the use of a good grade of peat and muck.

Comparisons of the effectiveness of various kinds of peat recommended for use should take into consideration the relative value of the organic material from the standpoint of improving granula-

tion of a soil; its effectiveness in lowering volume-weight and increasing permeability for air and roots of plants; the greater capacity to retain water and salts and thus diminish run-off and erosion, and its chemical effects, through the formation of carbon dioxide, in releasing soil solutions for use by micro-organisms and growing plants.

Considerations of the respective quality and value of several kinds of peat indicate that a grade of light-colored, poorly decomposed fibrous moss, reed, or sedge peat is better adapted to meet the needs of horticultural purposes and most effective from a standpoint of improving unfavorable structural properties of a soil, moisture deficiency, and of releasing soluble salts and nutrients during decomposition. In these respects a shredded medium- to coarse-textured material is more effective in improving the condition of heavy clay soils and is more suitable for sandy soils.

Grades of reed, sedge, and moss peat which are dark in color and have undergone partial decomposition are of value to any mineral soil, but they afford improvements that are largely due to changes in the physical properties of a soil. They have a lower moisture-holding capacity and a lower content of decomposable constituents for chemical action and the activities of micro-organisms; they are consequently more resistant to further decay and may persist in the soil over an extended period, depending on environmental conditions. In this respect reed and sedge peat contain comparatively more residue that persists as such than moss peat.

Peat and muck that have been dried artificially or charred are relatively less suitable grades of organic material because of their greatly reduced capacity to retain water. Although black in color and granular in texture, they are more or less inert, oxidize very slowly, and their practical disadvantage may be intensified by excessive percolation and a physical deterioration of the soil consequent to its open structural condition.

In general, it may be stated that the use of fibrous and partially decomposed grades of domestic peat, well mixed with a mineral soil, will result in a general increase in plant growth when cognizance is taken of the particular nutrient demands of the plants. In regions where mineral soils contain lime and soluble salts or where rainfall during the summer months is often light and there is danger of drought, an application of poorly decomposed, shredded moss peat or reed and sedge peat added to light sandy soils or to heavier soils such as silt and clay will do much to improve their structure and moisture-holding capacity.

On the other hand, in regions where the growing seasons are short and the climatic conditions are cool and humid, it is of greater importance that grades of peat or muck, dark in color and more or less advanced in degree of decomposition, be used. The soil mixtures are usually less retentive of moisture, better drained, and definitely warmer, and they can be worked earlier in the spring.

It is essential to know both the limitations and possibilities of the peat resources of the United States and to select the areas of peat that are of economic importance in the production of commercial peat products.

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